ENGINEERING CASE LIBRARY

ECL 43

PETERSON TRACTOR COMPANY (A)

Design of a Side Sloper

On August 2, 1965, Roy Barnes, a designer in the Special Equipment Department at the Peterson Tractor Company, San Leandro, California, began working on the layout for a side sloper to be attached to the bulldozer blade on a Caterpillar Model 834S wheel-type tractor. A side sloper is an auxiliary blade attached to the end of the bulldozer main blade for cutting a slope at a certain angle -- in this instance, a fixed angle -- relative to the cut taken by the main blade. The side sloper was to be built for Peter Kiewit Sons' Company, one of the contractors on the Feather River water project in California. The sloper would be used on a section of the San Luis Canal which was being built to carry water 103 miles from the San Luis Reservoir near Los Banos to Kettleman City near the Tehachapi Mountains, from where the water was to be pumped to Los Angeles. PKS[1] would use the sloper to cut the banks of the canal; the banks and floor would then be lined with concrete by another contractor.

Peterson is a dealer for the Caterpillar Tractor Company. The Special Equipment Department is responsible for modifications and attachments to various models in the Caterpillar line to suit the special needs or requests of purchasers. The department consists of about 30 people. Roy is one of two designers working under the Chief Engineer. Roy's work is concerned with construction equipment; the other designer is mainly occupied with the specification of stationary powerplants to suit customer applications.

[1]PKS is the abbreviation for Peter Kiewit Sons' Company

Prepared in the Design Division of the Mechanical Engineering Department by John Alic under the direction of H. O. Fuchs, with financial support of the National Science Foundation. The cooperation of Roy Barnes of the Peterson Tractor Company is gratefully appreciated.

Roy had been employed at Peterson since March, 1964. After three years spent studying engineering at Northwestern University, he worked at the Caterpillar main plant in Peoria, Illinois, for six years as a tool designer, designing jigs and fixtures for production machining operations. His last two years there were spent designing tool holders, tool posts and workpiece holders for automatic lathes. After coming to California, Roy spent two and a half years as a designer at Temescal Metallurgical Corporation, a specialty metals firm in Berkeley. There he designed electron beam refining furnaces and evaporation chambers for the vacuum deposition of such metals as aluminum, copper and silicon. He also designed vacuum valves, including two 48 inch gate valves for a wind tunnel at NASA's Ames Research Center. At various times he had as many as three draftsmen working under his supervision.

At Peterson Roy divides his time between design work on the drafting board, supervision of the fabrication of his designs in the shop, and observation of the operation of equipment on the job after it has been completed and delivered. Roy said that if a piece of equipment he has worked on gives trouble in the field, he may take a couple of welders with him to watch it in operation and correct problems over a period of several days, or even, in some instances, several weeks.

One of the projects Roy has worked on at Peterson has been a high-speed compactor used to compress the earth and gravel forming the foundation for a highway. Ordinary compactors are limited to four to five mph. Peterson took a Caterpillar scraper, replaced the bucket by a fabricated beam (simply to hold the two halves of the machine together) and installed steel-toothed compactor wheels filled with lead in place of the original rubber tires. The resulting machine can reach a speed of around 25 mph, but since it has no suspension the driver may not manage to stay aboard very long at such speeds.

Another job Roy worked on entailed connecting together three large scrapers in a train, all three being under the control of one operator. Ball-jointed hitches were used between each scraper and a set of controls was designed which would allow the single operator to control all three machines from a cab on the rear one while leaving the standard controls in place so that the scrapers could still be used individually if desired.

The San Luis Canal was to be 110 feet wide at the bottom and more than thirty feet deep. PKS was the contractor on a stretch of canal about 30 miles in length. Because of the size of the job, they had decided that they could afford two side slopers for cutting the banks. While such slopes could be cut with a motor grader, the job can be done faster and with greater precision -- thus more cheaply -- with a side sloper. Kiewit felt that two slopers, at several thousand dollars apiece, would easily pay for themselves. The job was expected to take about two years. Roy Barnes said he thought that both slopers would probably be worn out by the time the 30 miles of canal were finished; that is, that the moldboards (the large curved sheet on a side sloper, or bulldozer, which supports the cutting edge and pushes the dirt after it has been cut) would be worn thin.

Although Kiewit was purchasing the slopers specifically for this job, Roy did not think that they would be scrapped after its completion since the slope they were to cut was a common angle and the moldboards could easily be renovated by welding a new, thinner sheet of steel on top of the original one.

Although Peterson had been making side slopers for more than ten years, they all tended to be different in detail, and new drawings had to made for each. Roy had also designed the first side sloper for Kiewit, one which had been welded to the 834S bulldozer blade. The new one was to be bolted on, and since experience with the first had shown that a change in the curvature of the blade would be desirable, Roy had to start an all-new layout. A detachable side sloper was desirable since the sloper extends almost eight feet to the side of the dozer and hinders normal use of the machine. A bolt-on sloper can be added or removed much more quickly than the dozer blade can be changed. In addition, a dozer blade costs $7,000, so that the conversion of one to a single purpose side sloper costs much more than does a detachable sloper alone. The first sloper was permanently attached to a blade by welding because the device could be fabricated much more quickly by this method, and Kiewit needed it in a hurry.

When Kiewit decided that they wanted a second sloper, their Job Superintendent on the canal project phoned the Executive Vice President of Peterson Tractor Company, R. A. Peterson, who then talked to Roy. While the price to Kiewit of the first sloper had been determined after its completion, on a cost-plus basis, the price of the new one was set before fabrication began. It was based on the cost of the first one with an added charge for making the new sloper detachable.

Mr. Peterson passed on certain specifications to Roy as given him by Kiewit and added others which came from his long experience with construction equipment and from his observations of the first sloper performing on the job. Roy did not receive any written instructions at this time, and a purchase order for the sloper did not reach the Special Equipment Department until he was about halfway through his layout.

The design specifications, as he understood them from his conversation with Mr. Peterson, may be paraphrased as follows:

1. That the blade be angled forward 30° in plan view. (The first sloper had been built at this angle, which had originally been specified by Mr. Peterson. This is about the same as the usual blade angle on motor graders.)
2. That the blade be angled to cut a 2:1 slope; that is, that the ratio of blade run to blade rise be 2:1 in a front elevation, where blade run is the length along the horizontal ground line and blade rise is the displacement of the off-end of the blade relative to the ground line. (Specified by Kiewit.)
3. That the blade be approximately eight feet in length along its cutting edge. A standard eight inch wide, 92 inch long purchased cutting edge would be bolted onto the blade base which, in turn, would be bolted to the moldboard. (Specified by Kiewit.)
4. That the blade cutting angle be 45° relative to the canal floor in the plane perpendicular to the bulldozer blade. (A judicious choice by Roy.)
5. That the end of the moldboard adjacent to the dozer blade be curved on a 30 inch radius through 60° in the plane perpendicular to the dozer blade. (Specified by Mr. Peterson.)
6. That the off-end of the moldboard be curved on a nine inch radius through 75° in the plane perpendicular to the dozer blade. (This radius had been 12 inches on the first sloper; from his observations of the first one, Mr. Peterson specified this change to improve the roll of the dirt).
7. That the sloper be attached to the dozer blade by one inch (minimum) bolts. (Specified by Mr. Peterson.)

Roy's first problem was then to lay out that section of the moldboard which was to be curved. He needed a true view to 1/8th scale of the flat sheet of steel before bending. After this he would add a one-inch wide flat section to its bottom edge to which the blade base could be bolted and a large "flat" section above the curved portion of the moldboard extending to a level with the top of the main dozer blade. This latter addition was primarily for appearance. It took Roy about 12 hours over a two day period to finish the design of the moldboard. This was the only design project he was working on at that time. He did not design any of the braces and gussets, or the attaching brackets, on paper. The side sloper is shown under construction in Exhibit 2, butted against the dozer blade, and after completion in Exhibit 3.

The blade base and the flange plate on the near end of the sloper which butts against the dozer end wing, are shown in Exhibits 4 and 5. The blade base backs up the cutting edge and allows the cutting edge to be flat so that it can be reversed when one edge is worn. Note that while the intersection of the cutting edge with the flange plate forms an angle of 45° with the horizontal, the blade base incorporates a further bend. During their conversation, Mr. Peterson had first told Roy to make the blade cutting edge angle 45° in the plane perpendicular to the bulldozer blade. Roy suggested that it would be easier to design the sloper if the cutting angle was made 45° relative to the cut slope in the plane perpendicular to the sloper edge. Mr. Peterson had no objections, but Roy later found that it was easiest to do as shown in Exhibit 5.

Fabrication of the side sloper began on August 4. On this day and during the following two or three days, Roy spent about half his time working with the shop on the fabrication of the sloper in lieu of making further detailed drawings, which would have taken a greater total amount of his time. With a true view of the flat, unbent moldboard, he had made a full size cardboard template for the shop to use in laying out the moldboard. The moldboard was then cut out of 5/16 inch low alloy steel plate with a hand held torch. The steel used was one combining high resistance to abrasion with good forming and welding properties. In addition, he made two templates to fit the curves at the ends of the moldboard, to be used when it was being bent into shape. These were particularly important since these curves are non-circular in the plane perpendicular to the sloper cutting edge.

Since Peterson does not have a roll, the moldboard was curved to shape by making many light bends in a press brake. Roy also laid out guide lines in chalk on the shop floor to aid in correct alignment of the sloper during fabrication.

A total of 24 one-inch bolts hold the sloper to the dozer blade. Roy placed many bolts in areas where they would be in tension, fewer at points where the brackets would be in compression and the bolts in shear only. The steel tubing braces which may be seen on the back of the sloper, most other braces, the gussets, and the box structure which reinforces the moldboard also were made the same as on the first sloper built for PKS, although for this second one the braces were bolted to the dozer. The bolted connections were made as follows: a clearance hole for the bolt was drilled at the appropriate place on one of the attaching brackets of the sloper. Then a rectangular plate was cut out of one inch thick steel and drilled and tapped for one or more bolts. These plates then were bolted up to the sloper, and the sloper was positioned against the dozer blade. The plates were next welded to the dozer, correct location being thus ensured. Roy said that this method of attachment is commonly used on construction equipment because locating problems are minimized and the small pieces of steel plate can be easily drilled and tapped in a drill press, while these operations would be quite difficult to accomplish on a large unwieldy dozer blade or other piece of equipment. As

a further reason for this method of attachment, the dozer end wing, which butts against the flange on the sloper, is 5/8 inch steel, insufficient for the desired one inch thread depth with a one inch bolt.

The side sloper was completed on August 17.

Suggested Assignments

1. Show a long edge of the side sloper blade base in its true relation to the bulldozer in front view, side view, and top view. Front, side, and top are taken relative to the bulldozer. Assume that the cutting edge extends one inch below the blade base in Exhibit 4.
2. Determine angle β shown in Exhibit 5.
3. Determine dimensions a and b, shown in Exhibit 5.
4. Draw the side sloper moldboard in the three views, front, side and top relative to the bulldozer. To simplify the problem, assume that the moldboard is curved through 75° in the plane perpendicular to the bulldozer blade at both ends. If problem 2 had not been solved, assume angle β to be 15°.
5. Develop the curved part of the side sloper moldboard assuming 75° arcs at both ends.
6. Develop the flat plate patterns for cutting out the entire moldboard.

CATERPILLAR

834 Wheel-Type Tractor

834 Tractor equipped with 834S Bulldozer

BULLDOZERS —

- Straight Blade
  14'8" x 57" (4470 mm x 3734 mm)
- Cushion Blade
  12'3" x 57" (3734 mm x 1448 mm)
  Absorbs 100,000 lb. (45359 kg) of force.
- Hydraulic, single lever control of tilt & tip.
- Dozer-length Skid Plates

MANEUVERABILITY with 29.5-35 Tires —

- Articulated frame design with hinge point midway between front and rear axles.
- Front and rear wheels track at all times.
- Turning radius of 21'0" (6401 mm)

STABILITY —

- Long 150" (3810 mm) wheelbase.
- Wide 100" (2540 mm) tread.
- Approx. weight of 76,000 lb. (34 500 kg).

DIESEL POWER —

- Caterpillar 400 flywheel horsepower engine.
- Automatic, fuel-injection timing advance for optimum performance at all RPM.

POWER SHIFT TRANSMISSION —

- Caterpillar-built, planetary type.
- Controlled by single lever giving three forward and reverse speed ranges over 20 MPH (32 km/h).

AE4039605 (6-66)

834 WHEEL-TYPE TRACTOR

CATERPILLAR ENGINE:

Flywheel Horsepower @ 2000 RPM........... 400

Flywheel horsepower is net usable HP at flywheel of standard engine operating under normal temperature and barometric conditions up to 5000 ft. (1500 m) altitude. Standard engine equipment includes fan, air cleaner, water pump, lube oil pump, fuel pump and charging alternator.

N.A.C.C. H.P. for U.S.A. tax purposes 70

Maximum Torque

	FT. LB.	(mkg)
With fan at 1400 RPM	1235	(171)

Design Data

Model D343, four-cycle, 5.4" (137,2 mm) bore and 6.5" (165,1 mm) stroke, six-cylinder diesel. 893 cu. in. (14,634 lit) displacement.

Pressure-ratio controlled turbocharger and after-cooler. Parallel manifold porting with two intake and two exhaust valves per cylinder. Valves directly actuated by overhead camshafts. Variable Timing fuel system. Adjustment-free fuel pumps, non-fouling injection valves and precombustion chamber design.

Uses economical No. 2 Fuel Oil (ASTM Specification D396-48T), often called No. 2 furnace or burner oil, with a minimum cetane rating of 35. Premium-quality diesel fuel can be used, but is not required.

Starting Methods, Choice of:

Direct Electric Diesel Starting (24-volt motor)

Gasoline Engine Diesel Starting (12-volt gas engine starter)

TORQUE CONVERTER: Single stage, single phase with 3.29:1 stall ratio.

TRANSMISSION: Full power shift in all three ranges forward and reverse. Single lever shifting.

DIFFERENTIAL: Conventional.

AXLES: Front axle fixed, rear axle oscillates ±15° total of 30°. One wheel can drop or rise ± 25¾" (±650 mm) with all wheels remaining on ground for maximum traction. Axles may be removed independently of wheels and planetaries.

FINAL DRIVES: All-wheel drive with planetary reduction in each wheel. Planetary units may be removed independently of wheels and axles.

TIRES:

Wide-base, tubeless type with abrasion and cut-resistant compounding. Rock or traction tread.

Standard	29.5-35 (22 PR)
Optional	33.25-35 (20 PR)
Optional (Extra Tread Rock)	33.25-35 (20 PR)

FRAME:

Two frames fabricated from steel plate and rolled sections. Joined at the center by two hardened steel pin, 4¼" (108 mm) in diameter. Manganese bronze sleeve-type upper bearing and double tapered roller lower bearing.

STEERING:

Articulated frame. Full hydraulic, constant velocity type, with mechanical follow-up for automotive feel.

Turning Radius —

Outside of tires	21'0"	(6400 mm)
Outside corner of straight bulldozer	23'8"	(7214 mm)
Outside corner of cushion bulldozer	22'10"	(6960 mm)

Steering Angle (each direction) .... 44°

Hydraulic System — Two 5" (127 mm) bore, double-acting cylinders powered by vane-type, tandem sectional pump:

Output @ 2000 RPM with 1000 PSI (70 kg/cm²):

Large Section	80 GPM	(303 lit/min)
Small Section	13 GPM	(49 lit/min)

Relief Valve Setting

Large section	2000 PSI	(141 kg/cm²)
Small Section	2500 PSI	(176 kg/cm²)

SPEEDS:

GEAR	FORWARD MPH	FORWARD (km/hr)	REVERSE MPH	REVERSE (km/hr)
1	0- 3.4	(5,5)	0- 4.1	(6,6)
2	0- 7.8	(12,6)	0- 9.3	(15,0)
3	0-20.4	(32,8)	0-22.2	(35,7)

BRAKES:

SERVICE — Self-adjusting, 4-wheel, full hydraulic expander tube design. 12 equally spaced shoes in a 26" (660 mm) diameter x 5" (127 mm) wide drum.

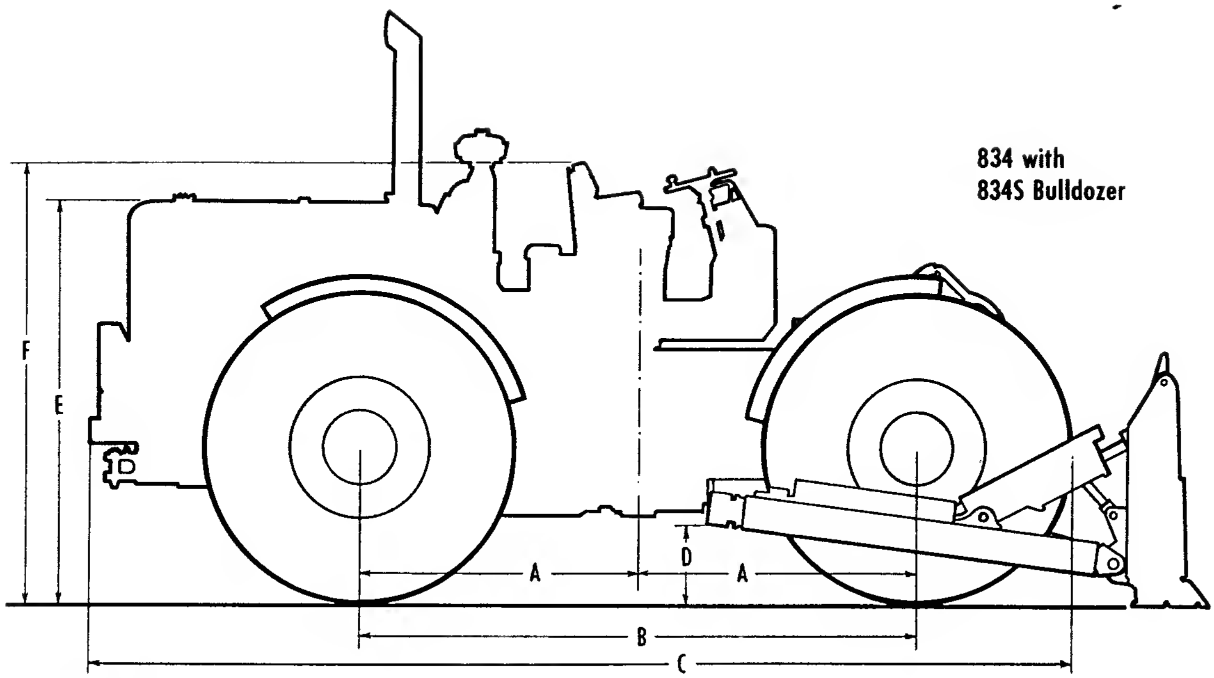
PARKING — Mechanical type, internal expanding, 12" (305 mm) x 5" (127 mm) parking brake acts on transfer drive.

STANDARD EQUIPMENT:

Sealed 12 or 24-volt alternators and batteries, reversible fan, dry-type air cleaner, air cleaner service indicator, electric horn, electrical disconnect switch with key, fuel priming pump, lockable instrument panel cover, steering wheel spinner knob, retractable ladder, fenders, and drawbar. Gauges: engine jacket water and torque converter oil temperature. Ammeter. Engine oil, fuel, and brake hydraulic pressure.

OPTIONAL EQUIPMENT:

Straight and Cushion Bulldozers (see back page) push cup, push plate and end bits. Windshield wipers, cabs, curtains, defrosters, heaters and lighting systems. Fuel tank, radiator, oil filler, and hydraulic tank cap locks. Push block and iron counterweights. Automatic torque-proportioning differential. Drive shaft and engine guards, fan blast deflector. Ether starting aid, rain cap and tool kit.



DIMENSIONS:

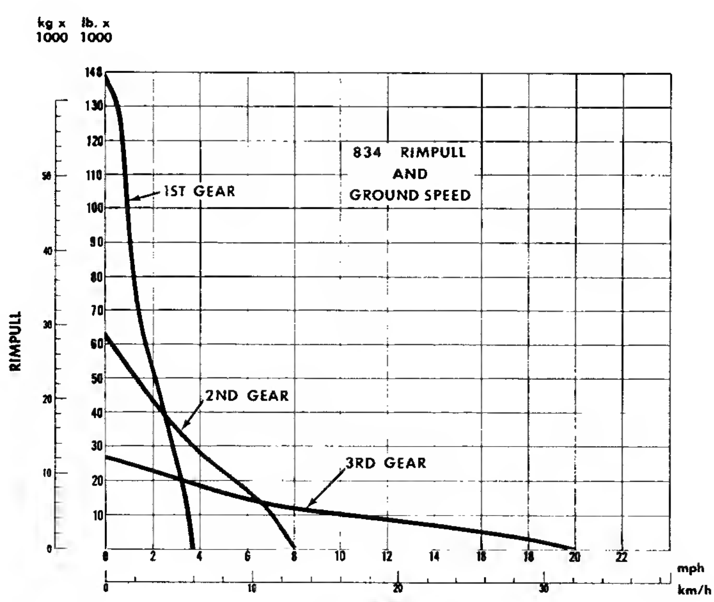
"A" Pivot pin to axle center	75"	(1905 mm)
"B" Wheelbase	150"	(3810 mm)
"C" Overall length w/o dozer	22'3¾"	(6801 mm)
With straight dozer	25'5"	(7747 mm)
With cushion dozer	26'4"	(8026 mm)
"D" Ground clearance	19⅞"	(505 mm)
"E" Height to top of radiator	8'4⅜"	(2550 mm)
"F" Overall height	9'3"	(2820 mm)
Overall width	11'2¾"	(3423 mm)
With straight dozer	14'8"	(4470 mm)
With cushion dozer	12'3"	(3734 mm)
Tread	100"	(2540 mm)

SERVICE CAPACITIES:	U.S. Gal.	Liters
Fuel tank	185	(700)
Cooling system	27	(102)
Lubricating system:		
Diesel engine crankcase	9¾	(37)
Transmission	26¼	(99)
Differentials (front)	8¼	(31)
(rear)	9¾	(37)
Final drive (each)	5½	(21)
Hydraulic tank	30½	(115)

SHIPPING WEIGHT, APPROX.:

834 Tractor — 29.5-35 (22 PR) Tires and direct electric starting system. Includes lubricants, coolant and 10% fuel in fuel tank.

With 834S Bulldozer .... 76,000 lb. (34 500 kg)
With 834C Bulldozer .... 73,000 lb. (33 000 kg)



Usable rimpull will depend on traction and weight of tractor.

834
Wheel-Type Tractor

Bulldozers

Complete bulldozer consists of blade, push arms, stabilizing member, trunnion mounting, dozer length skid plate with replaceable wear plates, reversible cutting edges, self-sharpening end bits, hydraulic lift cylinder, tip and tilt cylinders, hydraulic lines guard (834S Bulldozer only), three spool control valves.

	834S	834C
BLADE:		
Length	14'8" (4470 mm)	12'3" (3734 mm)
Height	57" (1448 mm)	57" (1448 mm)
Ground clearance below skid shoe, max.	38" (965 mm)	36" (914 mm)
Depth of cut, max.	18" (457 mm)	22" (559 mm)
Tilt adjustment (from horizontal)	48" (1220 mm)	13" (330 mm)
Tip adjustment, max.	22°	25°
Lift speed, ft/sec (at rated RPM)	1.9 (580 mm/sec)	2.0 (610 mm/sec)
Construction	Multiple box section	
Maximum contact speed, (MPH)	———	3 (4,8 km/hr)
Force required for maximum cushion blade deflection, lbs.	———	100,000 (45350 kg)
MOLDBOARD:		
Material	HT Steel	
CUTTING EDGES (2), reversible:		
Length, each	69⅞" (1775 mm)	55½" (1410 mm)
Width x thickness	10" x 1" (254 x 25 mm)	10" x 1" (254 x 25 mm)
Material	"Hi-Electro" hardened steel	
END BITS (2), self-sharpening:		
Length, each	18" (457 mm)	18" (457 mm)
Width x thickness	10" x 1" (254 x 25 mm)	10" x 1" (254 x 25 mm)
Material	"Hi-Electro" hardened steel	
SKID PLATES, reversible:		
Number	3	2
Length, center section	51⅞" (1318 mm)	———
Length, end sections	45⅞" (1165 mm)	43⅞" (1114 mm)
Width x thickness	10" x 1" (254 x 25 mm)	10" x 1" (254 x 25 mm)
Material	"Hi-Electro" hardened steel	

HYDRAULIC SYSTEM:
Two control levers, one for lift and one for tip and tilt.
Lift lever has raise, lower, hold, and float positions.
Hydraulic oil is full flow filtered.

	834S	834C
Pump, vane-type Output [@ 2000 RPM and 1000 PSI (70 kg/cm²) with S.A.E. No. 10 oil @ 150° F. (66° C.)].	80 GPM (303 lit/min.)	80 GPM (303 lit/min.)
Relief valve opening pressure	1800 PSI (127 kg/cm²)	1800 PSI (127 kg/cm²)

HYDRAULIC CYLINDERS (double acting):
Bore x stroke:

	834S	834C
Lift	6½" x 36" (165,1 x 914 mm)	6½" x 29½" (165,1 x 749 mm)
Tip, left side	6" x 10" (152,4 x 254 mm)	6½" x 10⅝" (165,1 x 269 mm)
Tip and tilt, right side	6½" x 10" (165,1 x 254 mm)	———
Double ended	———	6" x 10⅝" (152,4 x 269 mm) 6" x 3" (152,4 x 76 mm)

CATERPILLAR

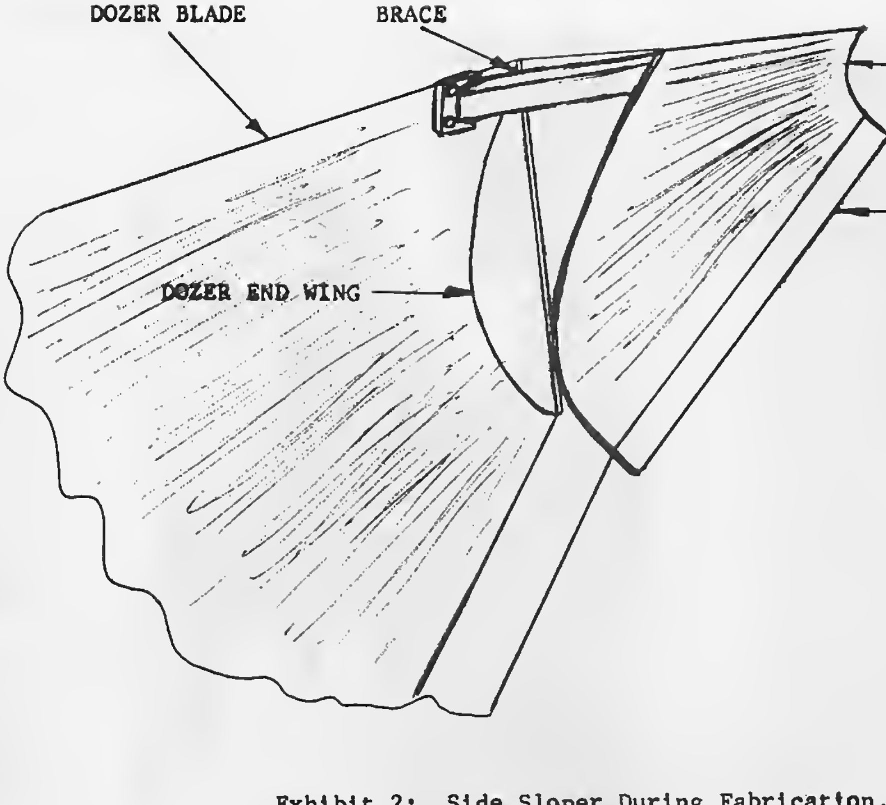


Exhibit 2: Side Sloper During Fabrication.

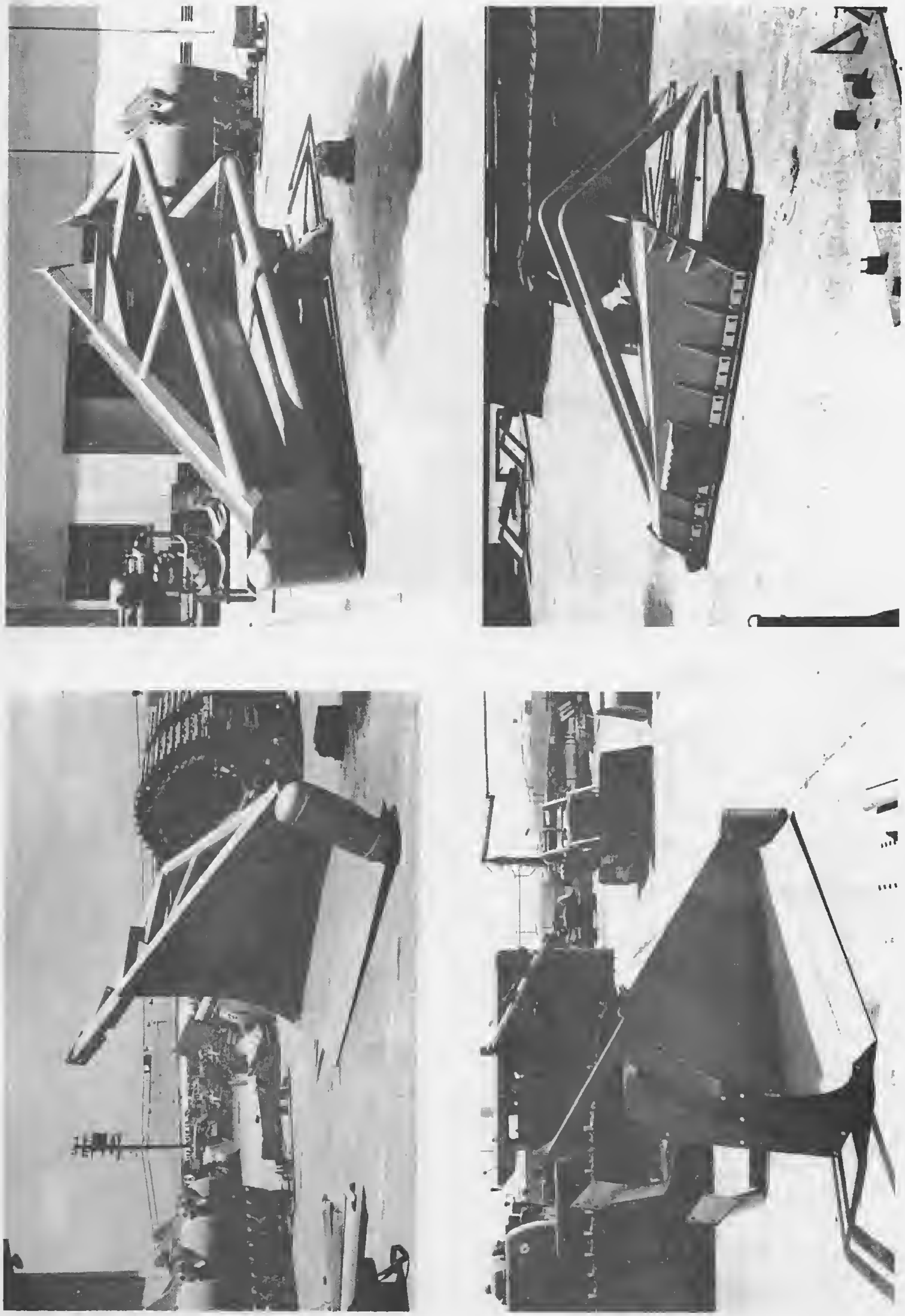


Exhibit 3: Completed Side Sloper.

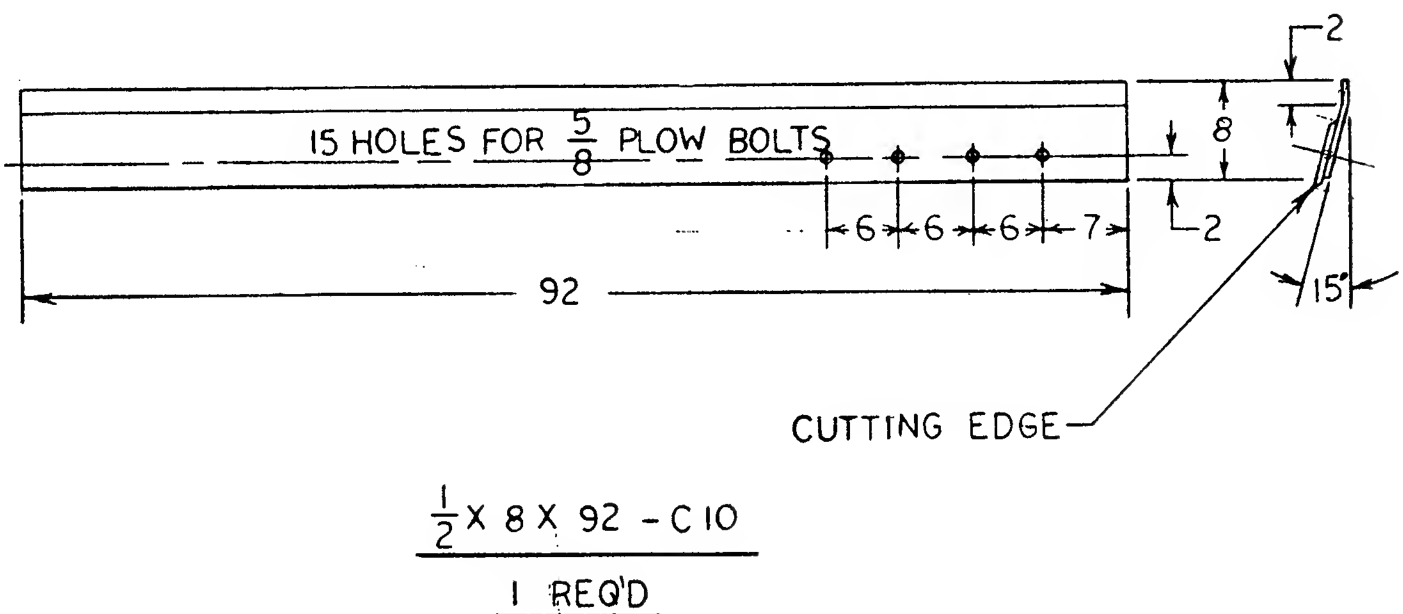


Exhibit 4: Blade Base. Cutting Edge Shown in End View Only. Redrawn for Case Study Presentation.

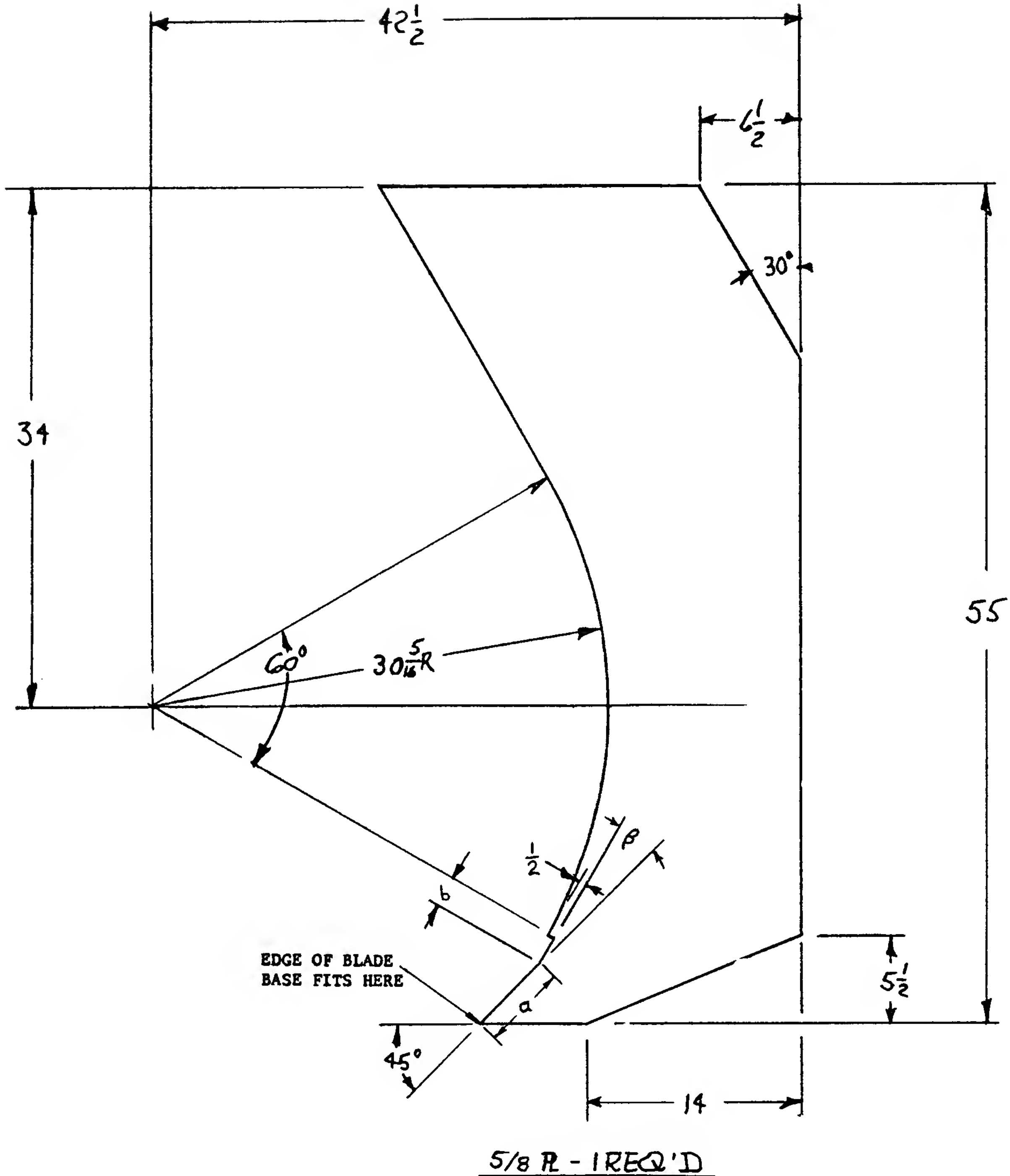


Exhibit 5: Roy Barnes' Drawing of the Side Sloper Flange Plate with Slight Modifications. Plate is Bolted to Dozer End Wing. View Perpendicular to Dozer Blade.

PETERSON TRACTOR COMPANY (B)

Instructor's Remarks on the Peterson Tractor Case

The problem faced by Roy Barnes could be solved in many different ways. For instance, he could have made a sheet metal model of the bulldozer moldboard and of the bank of the canal. He could then have taken a flexible material such as heavy aluminum foil and shaped a side sloper by using scissors and his fingers, making changes until Mr. Peterson's specifications were satisfied. This small scale model could then be handed to the shop with instructions to reproduce it on a large scale, or it could be photographed against grids, or dimensions for a sketch or drawing could be taken from it.

As only a single side sloper needs to be made, Roy Barnes need not be too precise in describing it to the shop. The shop can make a side sloper which fits a model or drawing fairly closely and then attach it to the bulldozer moddboard. The situation would be entirely different if Peterson were buying fifty side slopers from an outside vendor. Roy would then have to describe the basic desired shape and those variations from the ideal shape which are permissible. He would use large tolerances for low cost, but even the large tolerances would have to be precisely defined. The same would be true if parts for the side sloper were to be made in different departments of one factory. When the various parts come together for assembly they must fit. If the drawings or instructions are vague or ambiguous, then the parts will not fit and each department will blame the other for the difficulty.

We will use descriptive geometry rather than a physical model to find the location of the elements which satisfy Roy's seven specifications. We will then connect the specified elements by well-defined geometrical surfaces and obtain the basic shape of the side sloper. We shall assume that the side sloper is bounded by two planes: the flange plate and a plane parallel to it at the other end of the cutting edge. Margins for overlap etc. can easily be added to this basic shape after it has been drawn.

In order to do this job without wasting too much time, it is necessary to follow a plan. The beginner may not be able to formulate the complete plan at first. If this is the case, he should formulate a plan leading partway to the desired solution, execute that plan, then sit back and see if he can devise a plan to lead from there on. Aimless drawing of lines from one view to another is a pure waste of time. The sequence of the suggested assignments provides the skeleton for a plan leading to the solution of the problem.

Assignment #1

We are asked to show a line on the 92 inch blade base in the correct position in front view, side view, and top view. Direction of the line in top view and front view is defined by specifications 1 and 2. The starting point is arbitrary. Assume a point O to be the apex of the angle β. One way to proceed is to assume a point **A** somewhere along the line which starts at point O and goes in the defined direction. Point **A** is assumed in one view and projected into the second view in which the direction of the line is known. From its position in two views we can establish its position in the third view. Now we project the segment OA onto a plane in which it appears in true length and lay out 92 inches along the line OA. The end point of the 92 inches may be called B. B can be projected back from the true length plane onto all the other planes. The line OB in front, top, and side views is the desired solution of Assignment 1.

Assignment #2

This assignment amounts to finding the intersection of two planes. One of these is the plane of the flange plate. The other is the plane of the 2 inch wide part of the blade base. This plane can be defined by the location of the three points, O, L, and M. O is the apex of the angle β. L is out, approx. 6" from O along the bend line of the blade base. M is a point where the free edge of the plane OLM intersects the flange plate. To solve this problem we start by going through the same steps as in the previous assignment. We have projections in four planes. Plane #1 is a plan view, Plane #2 is a front view, Plane #3 is the side view in which the angle β will later appear, Plane #4 is the plane in which any long edge of the blade base appears in true length. Therefore, the segment OL can be laid off in this plane in true length. Plane #5 is perpendicular to the segment OL. The segment OL appears as a point in Plane #5.

OL is now given in all five planes. We define point K as the point which is marked "Edge of Blade Base Fits Here" in Exhibit 5 of Part (A). The direction KO is given in the side view as 45° from either horizontal or vertical. We assume any point Q on the line KO. Point Q can be projected into the four other planes. The projection of point Q on Plane #5 defines the direction OQ. At 15° from this direction and at a distance of 2 inches from point O in Plane #5, we find point M in Plane #5. We can now project point M back into the other four planes and thus solve Assignment #2.

It will be convenient to project from the side view plane #3 to plane #4, because this gives an edge view of the flange plate in plane # 4.

Assignment #3

Length b was found above. Length a can be found by laying off 5 inches along OQ in plane No. 5 to point K and projecting point K back into planes No. 4 and No. 3.

Assignment #4

Solution of Assignments #1 and #2 is necessary in order to execute Assignment #4 and solution of Assignment #3 is very desirable. We assume all three have been executed. The upper edge of the blade base is known is all views. It connects two end points of the arcs defined by specifications #5 and #6 (and modified by Assignment #4). The angle β defines tangents to the arcs. We can lay out the two arcs in the side view and join their ends by a straight line. The two arcs and this straight line can be projected back into all the other views and the rearmost line in the moldboard drawn in the top view. Between the straight line which connects the upper ends of the arcs and the top of the moldboard we assume a plane. Four edges of this plane are known in side view. Two of the edges are tangent to the two arcs of circles and the third edge is horizontal at the level of the top of the flange plate. The fourth edge we have just drawn; it connects the top ends of the two arcs. In the front view the circular arcs are vertical lines. Knowing the four edges of the plane in two views, we can construct the plane in all the views. We can also construct a projection in which the plane appears in its true dimensions to satisfy part of Assignment #6.

Assignment #5

The curved surface of the side sloper is not completely defined by the outlines which we have established. These outlines consist of two straight lines and two arcs of circles. We want the curved surface to be one which can be developed into a flat sheet and be formed by successive bends in a press brake. A cone is such a surface. Two circular arcs in parallel planes, with equal included angles, define a circular cone. In our case this cone is not a right circular cone, but an inclined circular cone. We want to find the apex of the inclined circular cone, located at the intersection of the two straight edges of our curved surface. The line joining the centers of the arcs, the axis, also passes through the apex. Having located the apex, the axis, and two circular sections of the cone, we can construct the developed surface by laying out straight lines through the apex and determining the true length of these straight lines by geometric construction or by calculation. The straight lines preferably pass through points which are equally spaced at each circle so that both circular arcs can be developed into a number of straight lines of equal lengths.

Deviation from Mr. Peterson's Specifications

We deviated from specification #5 given Roy by Mr. Peterson in curving the large end of the dozer blade through 75° rather than through 60°. By doing this we obtained two advantages. The curved part of the side sloper moldboard could be defined as an inclined circular cone*, a surface which is easily defined and constructed. Also, the upper part of the side sloper now became a plane because it contained two parallel edges. If we had followed Mr. Peterson's instructions then the upper part of the side sloper could not be a plane because it would contain two edges which do not meet nor are parallel. They would be skewed with respect to one another. This upper part of the side sloper would have to be made either of two planes with a bend line between them or in some more complicated manner. The curved part of the side sloper would be a surface more complex than a circular cone. Whether this more complex surface could be developed or manufactured by a series of bending operations would have to be investigated. We believe that Mr. Peterson would not have objected to our deviation if its purpose had been explained to him. He might have asked us to use an angle other than 75° at both ends, but this would not have changed our program of solution, only the numbers which were inserted into the program.

We shall see that Roy Barnes did not alter Mr. Peterson's instructions. Since he had to make only one single side sloper, it was not necessary to define the surface in a rigorous way. He could go out into the shop and ask the men to bend and cut the sloper until it appeared acceptable. This was without doubt the most economical way to proceed under the circumstances. Students may compare the difference between the method used by Roy Barnes and the methods suggested in these notes, to the difference between the language used in ordinary conversation and the language used in patent specifications or legal contracts. Precise legal language seems more complex and cumbersome, but it can be clearly understood by the initiate without asking the speaker what he meant. Ordinary conversation can be kept simple because in case of doubt the speaker can furnish additional information. A well educated person should be able to understand precise communication and to use it in appropriate circumstances. If he uses it all the time he is pedantic; if he cannot use it in communicating plans and specifications he is no engineer.

Precision Communication

Caterpillar Tractor Company drawings of a cutting edge and of the plowbolt used to attach it are shown as examples of precision communication in Exhibits B1 through B6.

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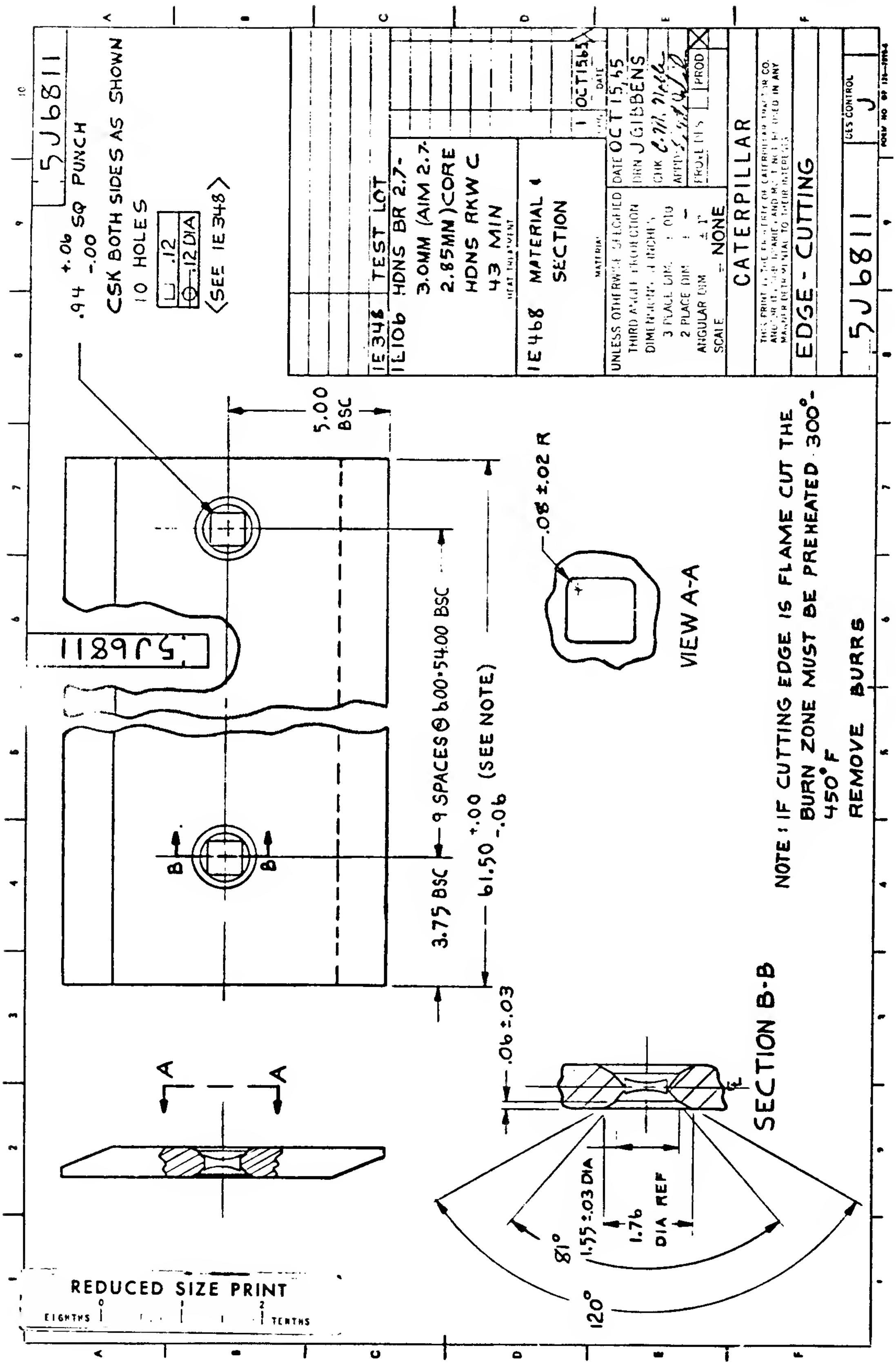
*Part of an inclined circular cone.

B1 gives the dimensions of this particular cutting edge. Note the tolerances; some of them are explained on B2 and B3. You may observe that B3 is change number 5 of this specification.

B4 is the stock from which various cutting edges are made. It is change number 4 but still contains an obvious error.

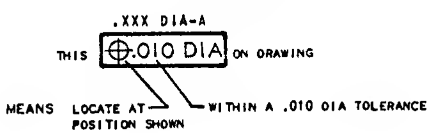
All engineers make errors (some make fewer than others). Note the "Prove Design" box in the drawing title block. The practice of making a final check of a design by building it catches errors before production release.

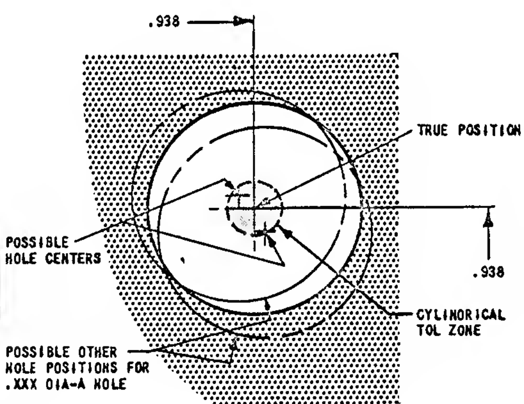
B5 and B6 describe the plow bolt. The revision made on October 7, 1965, probably involved a change in the method of specifying material and processing. The sheet of general dimensions (B6) saves time, promotes uniformity, and avoids errors made in copying. Observe the matching of the tolerances on the plowbolt and on the holes in the cutting edge.


5J6811
.94 +.06 -.00 SQ PUNCH
CSK BOTH SIDES AS SHOWN
10 HOLES
.12
.12 DIA
(SEE IE 348)
IE 348 TEST LOT
IL106 HDNS BR 2.7-3.0MM (AIM 2.7-2.85MM) CORE HDNS RKW C 43 MIN
IE 468 MATERIAL & SECTION
OCT 15 45
J GIBBENS
UNLESS OTHERWISE SPECIFIED
THIRD ANGLE PROJECTION
DIMENSIONS IN INCHES
3 PLACE DIM ±.010
2 PLACE DIM
ANGULAR DIM ±1°
SCALE = NONE
PROD
CATERPILLAR
EDGE - CUTTING
5J6811
J
5.00 BSC
.08 ±.02 R
VIEW A-A
NOTE: IF CUTTING EDGE IS FLAME CUT THE BURN ZONE MUST BE PREHEATED 300°-450°F
REMOVE BURRS
9 SPACES @ 6.00 = 54.00 BSC
3.75 BSC
61.50 +.00 -.06 (SEE NOTE)
.06 ±.03
SECTION B-B
1.55 ±.03 DIA
1.76 DIA REF
81°
120°
REDUCED SIZE PRINT
EIGHTHS
TENTHS

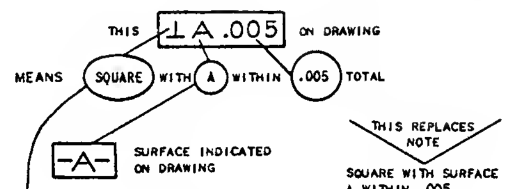
SYMBOLS FOR GEOMETRIC TOLERANCING

TRUE POSITION





A CIRCULAR FEATURE, LOCATED BY TRUE POSITION DIMENSIONS AND LOCATED WITHIN .XXX DIA OF TRUE POSITION, MEANS THAT THE AXIS OF THE FEATURE MUST LIE WITHIN A CIRCULAR TOLERANCE ZONE OF .XXX DIA WHOSE CENTER IS AT THE TRUE POSITION POINT.



GEOMETRIC CHARACTERISTIC SYMBOLS THAT APPEAR ON CATERPILLAR DRAWINGS

SYMBOL	DEFINITION
⌒	FLATNESS AND STRAIGHTNESS
∠	ANGULARITY
⊥	SQUARENESS
∥	PARALLELISM
◎	CONCENTRICITY
⊔	ALIGNMENT
⌖	TRUE POSITION
○	ROUNDNESS
⌯	SYMMETRY

SYMBOLS FOR GEOMETRIC TOLERANCING

CATERPILLAR ENGINEERING SPECIFICATION

I. SCOPE:

THIS SPECIFICATION COVERS ENGINEERING REQUIREMENTS REGARDING PROCESSING OF HEAT TREATED PARTS HAVING RELATIVELY CLOSE TOLERANCED DIMENSIONS THAT ARE REQUIRED AFTER BEING HEAT TREATED. ALTHOUGH THIS SPECIFICATION PROVIDES A METHOD OF INDICATING CERTAIN SPECIFIC DIMENSIONS KNOWN TO REQUIRE SPECIAL CONSIDERATIONS, IT DOES NOT PRECLUDE THE FACT THAT ALL FINAL DIMENSIONS ARE REQUIRED AFTER HEAT TREATMENT AND ARE THE RESPONSIBILITY OF MANUFACTURING.

II. APPLICATION:

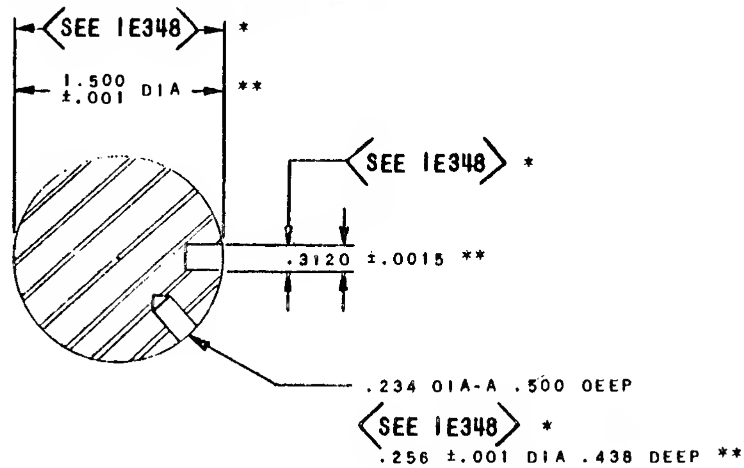
THIS SPECIFICATION IS APPLICABLE TO ANY HEAT TREATED PART WHICH REQUIRES ORIGINAL DETERMINATION AND/OR CONTINUING ADJUSTMENT OF ONE OR MORE PROCESSING DIMENSIONS TO PRODUCE THE REQUIRED SIZE AFTER HEAT TREATMENT.

III. GENERAL:

ALL HEAT TREATMENT CAUSES DIMENSIONAL CHANGES, TO ONE DEGREE OR ANOTHER, WHICH OFTEN CANNOT BE ADEQUATELY PREDICTED EXCEPT BY A TRIAL AND ERROR METHOD. TEST LOTS ARE BASED ON THE PRINCIPLE THAT ALL PARTS MACHINED ALIKE FROM THE SAME HEAT OF STEEL AND HEAT TREATED UNDER UNIFORM CONTROLLED CONDITIONS, WILL RESPOND SIMILARLY IN DIMENSIONAL CHANGE.

IV. DRAWING REQUIREMENTS: Δ

WHENEVER THE BRACKETED NOTE <SEE 1E348> APPEARS ON A DRAWING IT MEANS THAT A PROCESSING DIMENSION MUST BE DETERMINED AND USED ACCORDING TO THE DETAILS OUTLINED IN THIS SPECIFICATION BUT WILL NOT BE ADDED TO THE DRAWING. THE CLOSELY TOLERANCED DIMENSION ON THE DRAWING IMMEDIATELY ADJACENT TO THE BRACKETED NOTE <SEE 1E348> IS THE DIMENSION REQUIRED ON THE FINISHED PART, AND IS NOT THE PROCESS DIMENSION. PREFERRED USE OF <SEE 1E348> IS SHOWN IN EXAMPLE DRAWING BELOW.



Δ

*THE BRACKETED NOTE "<SEE 1E348>" INDICATES TO THE PROCESSOR THAT:

A. THE CORRECT PROCESSING DIMENSION BEFORE HEAT TREAT, IN ORDER TO MEET THE REQUIRED SIZE AFTER HEAT TREAT, MUST BE DETERMINED BY THE PROCESSOR BY EITHER ESTIMATION, BASED ON A SIMILAR OR REFERENCE PART, OR BY A PRIOR "TEST LOT" WHOSE RESULTS CAN BE APPLIED TO THE REMAINDER OF THE PARTS IN THE TOTAL LOT.

B. THE CORRECT PROCESSING DIMENSION BEFORE HEAT TREAT MAY NEED TO BE ADJUSTED BY WAY OF ADDITIONAL TEST LOTS, TO ASSURE CONTINUING ATTAINMENT OF THE REQUIRED SIZE AFTER HEAT TREAT, AS A RESULT OF VARIATIONS BETWEEN HEATS OF STEEL, THE USE OF ALLOWED ALTERNATE STEELS, PROCESSING CHANGES, ETC.

**DIMENSIONS REQUIRED ON THE FINISHED PART.

NOTE: DRAWINGS HAVING GEAR DATA, SPLINE DATA AND SCREW THREAD DATA REQUIRING THE SPECIAL CONSIDERATIONS OF THIS SPECIFICATION WILL BE INDICATED BY "1E348 TEST LOT" IN THE SPEC BLOCK AND THE DATA MUST BE MET AFTER HEAT TREAT.

IN THE PAST DIMENSIONS REQUIRING THE CONSIDERATION OF 1E348 HAVE BEEN INDICATED BY THE NOTES "EXPECTED AFTER HEAT TREAT," "AFTER HEAT TREAT," OR "AS HEAT TREATED" IN CONJUNCTION WITH 1E348 IN THE SPECIFICATION BLOCK. THESE PARTS STILL REQUIRE THE CONSIDERATIONS OF 1E348.

V. ALTERNATE METHOD:

SUBJECT TO THE APPROVAL OF CATERPILLAR TRACTOR CO. ENGINEERING DEPARTMENT, SURFACES TO BE PROCESSED ACCORDING TO THE ABOVE PRACTICES MAY INSTEAD BE FINISHED MACHINED AFTER HEAT TREATMENT, PROVIDED THE RESULTANT HARDNESS, CASE DEPTH, DIMENSIONAL ACCURACY, ETC. OF THE FINISHED PART CONFORMS TO THE SPECIFIED LIMITS.

	DATE	CHG NO.	SPEC NO.
TEST LOT - HEAT TREATED PARTS	APR 23,64	5	1E348

Δ INDICATES CHANGE

CATERPILLAR ENGINEERING SPECIFICATION

I. **SCOPE:**

THIS SPECIFICATION COVERS HOT ROLLEO STEEL CUTTING EDGE STOCK IN ACCOROANCE WITH THE DETAILED DATA GIVEN BELOW.

II. **MATERIAL:**

MATERIAL SUPPLIED TO THIS SPECIFICATION SHALL MEET THE REQUIREMENTS OF 1E870.

III. **TOLERANCES:**

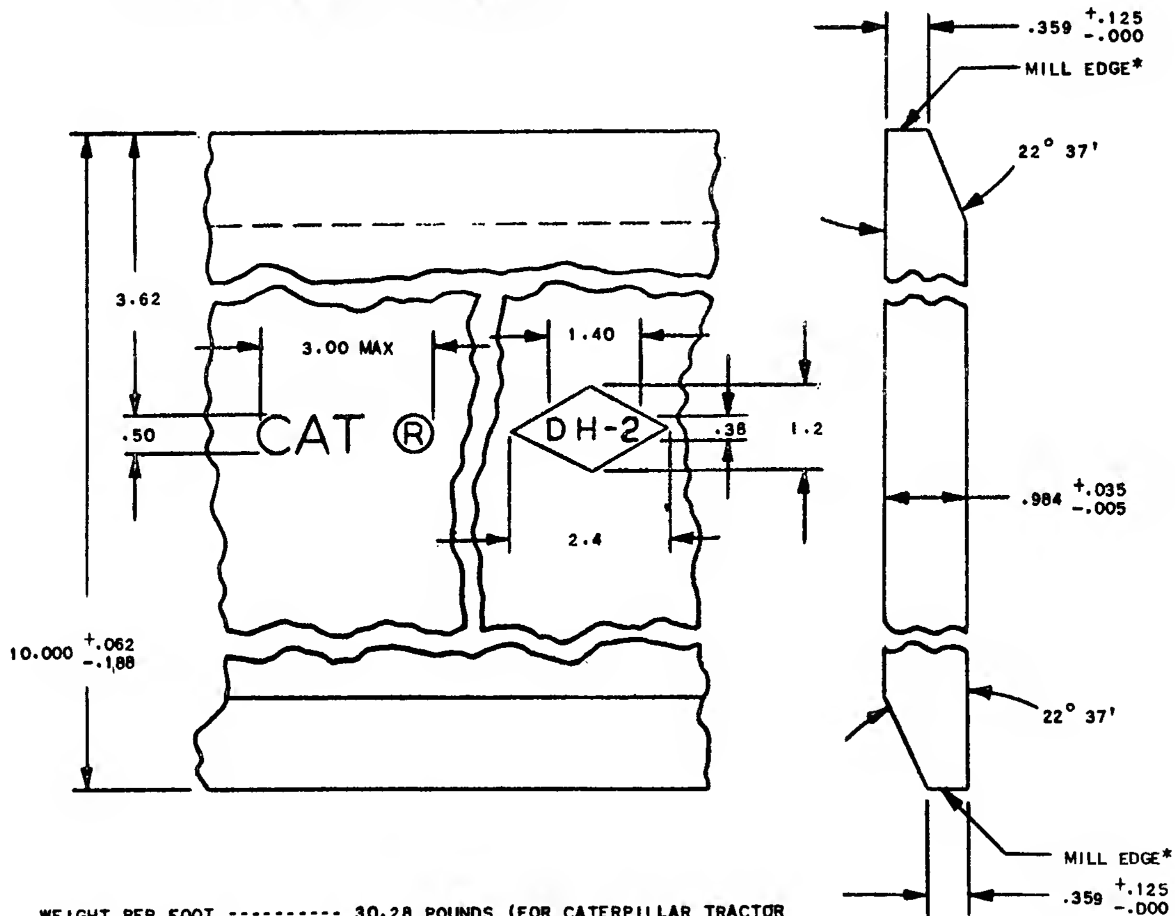
STRAIGHTNESS

CAMBER ---------- $.12 \times \frac{\text{NUMBER OF FEET OF LENGTH}}{5}$

BOW ------------- $.12 \times \frac{\text{NUMBER OF FEET OF LENGTH}}{5}$

IV. **MARKINGS:**

BRAND CATERPILLAR TRADEMARK IN ACCORDANCE WITH 1E198 TYPE E LETTERS WITH MAXIMUM CENTER TO CENTER DISTANCE OF 14 INCHES. REGISTRATION MARK SHALL APPEAR AS SHOWN WHEN ROLLED IN UNITED STATES. WHEN ROLLED ELSEWHERE REFER TO 1E198 FOR REGISTRATION MARK. SUPPLIER'S TRADEMARK MAY BE .38 INCH HIGH LOCATED BETWEEN AND ON THE SAME LINE AS THE CATERPILLAR TRADEMARKS. BRAND DH-2 MIDWAY BETWEEN AND ON SAME LINE AS CATERPILLAR TRADEMARKS IF THE SUPPLIER'S TRADEMARK IS NOT BRANDED IN THIS LOCATION. IF THE SUPPLIER'S TRADEMARK IS NOT BRANDED IN THIS LOCATION. IF THE SUPPLIER'S TRADEMARK IS BRANDED MIDWAY BETWEEN CATERPILLAR TRADEMARKS, BRAND DH-2 ADJACENT TO AND ON THE SAME LINE AS THE SUPPLIER'S TRADEMARK. ALL BRANOING IS TO BE RAISEO TYPE ONLY.



WEIGHT PER FOOT ---------- 30.28 POUNDS (FOR CATERPILLAR TRACTOR CO. GUIDANCE ONLY).

DIMENSIONS IN INCHES

* MILL EDGE - FULL RADIUS TO SHARP CORNERS

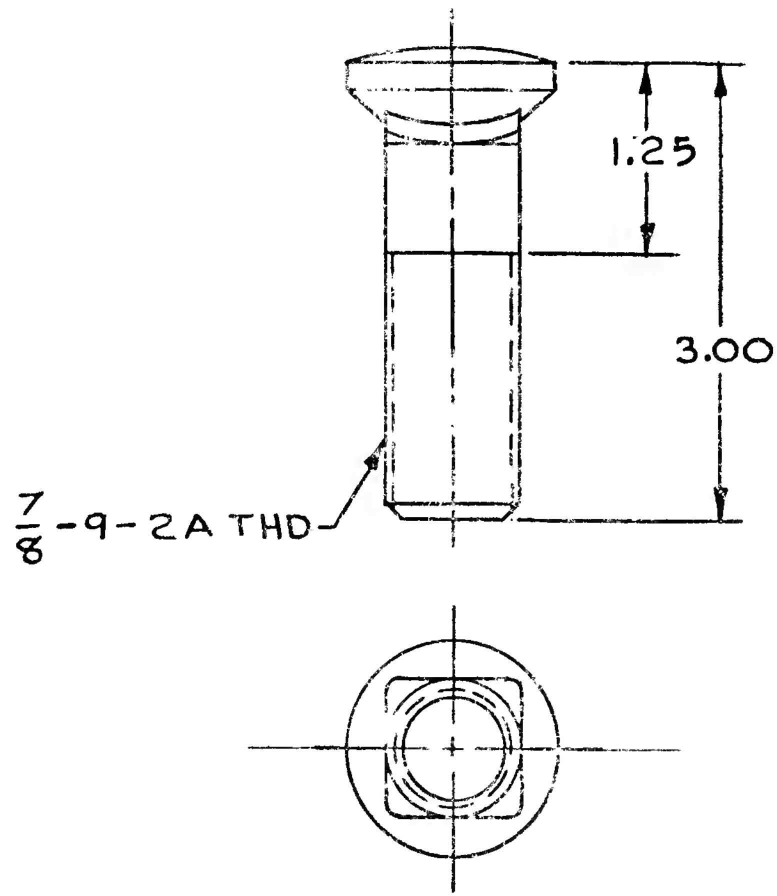
	DATE	CHG NO.	SPEC NO.
CUTTING EDGE - SECTION AND MATERIAL	JAN 7,65	4	1E468

P128-18497

Δ INDICATES CHANGE

REDUCED SIZE PRINT

EIGHTHS 0 1 2 TENTHS



REMOVE BURRS

IE44	DIM

HEAT TREATMENT

② ① IE2030 MATL. AND PROCESSING

MATERIAL

CHG	DATE
2	OCT 7,65
1	JUN 24,65

UNLESS OTHERWISE SPECIFIED
THIRD ANGLE PROJECTION
DIMENSIONS IN INCHES
3 PLACE DIM. ±.010
2 PLACE DIM. ±.
ANGULAR DIM. ± 1°
SCALE 1 = 1

DATE JAN 9, 64
DRN R TUEL
CHK [illegible]
APPD. [illegible]
PROVE DES | PROD.

CATERPILLAR

THIS PRINT IS THE PROPERTY OF CATERPILLAR TRACTOR CO. AND/OR ITS SUBSIDIARIES AND MUST NOT BE USED IN ANY MANNER DETRIMENTAL TO THEIR INTERESTS.

BOLT-PLOW

5J2409 | DES CONTROL | ∝

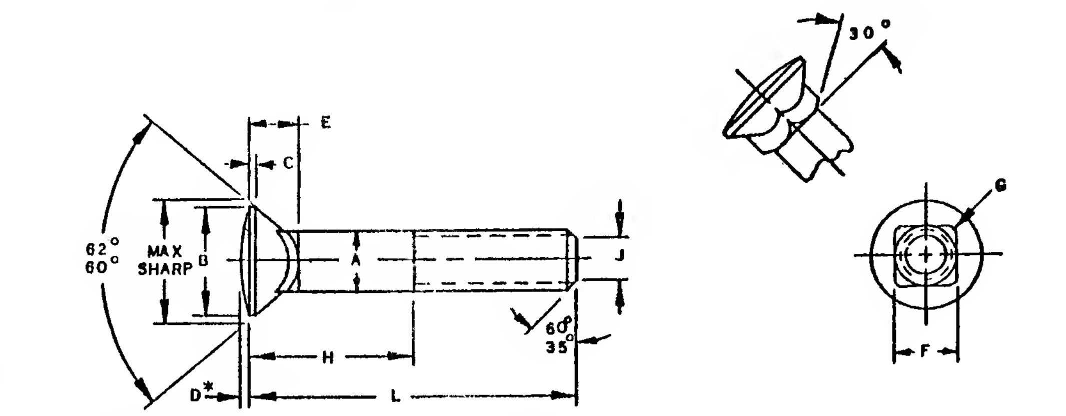
CATERPILLAR ENGINEERING SPECIFICATION

I. SCOPE:

THIS SPECIFICATION PRDVIDES DIMENSIONS AND TOLERANCES FOR NO. 3, 8D DEGREE RDUND COUNTER-SUNK HEAD, SQUARE NECK PLOW BDLTS. SIZES 5/15 THRU 7/15 HAVE FLAT HEAOS AND SIZLS 1/2 THRU I HAVE DOME HEADS.

II. BOLT DIMENSIONS:

FIGURE I LISTS OIMENSIONS ANO TOLERANCES FDR HEAD AND BODY.



* O APPLIES TD 1/2 THRU 1 INCH OIAMETER ONLY

NOM BDLT OIA	THD PER IN.	BDDY DIAMETER MAX	BDDY DIAMETER MIN	HEAO DIAMETER: MAX SHARP CDRNERS REF	HEAO DIAMETER: PRDDUCT LIMITS B MAX	HEAO DIAMETER: PRDDUCT LIMITS B MIN	FEED THICKNESS C MAX	DOME HGT D MAX	DEPTH OF HEAO ANO SQUARE E MAX	DEPTH OF HEAO ANO SQUARE E MIN	WIDTH OF SQUARE F MAX	WIDTH OF SQUARE F MIN	RADIUS ON CDRNER G MAX	TDLERANCE ON LENGTH L	POINT CHAM DIA J ±.DID
5/16	16	.313	.3D3	.605	.576	.563	.025	...	.269	.243	.325	.313	.031	±.031	.203
3/8	16	.375	.364	.708	.671	.655	.D31	...	.312	.281	.387	.375	.047	±.031	.250
7/16	14	.438	.426	.826	.761	.766	.036	...	.364	.328	.45D	.436	.D47	±.D62	.297
DIMENSIONS FDR 5/16 THRU 7/16 INCH DIAMETERS ARE IN ACCOROANCE WITH ASA B18.9 – 1958															
1/2	13	.50D	.466	.992	.890	.875	.07D	.06D	.445	.4D3	.515	.5DD	.D47	±.062	.359
5/8	11	.625	.611	1.197	1.044	1.013	.110	.08D	.536	.466	.640	.625	.078	±.125	.469
3/4	10	.75D	.735	1.454	1.2DD	1.169	.17D	.08D	.631	.581	.765	.750	.D78	±.125	.578
7/8	9	.875	.659	1.672	1.4D9	1.369	.16D	.090	.721	.656	.906	.675	.094	±.125	.688
1	8	1.00D	.963	1.66D	1.597	1.557	.160	.09D	.785	.722	1.D31	1.DDO	.D94	±.125	.781

FIGURE 1 - HEAO AND BODY DIMENSIONS

III. THREAD:

A. THREAD SHALL BE 1E500 CDARSE SERIES CLASS 2A.

B. THREADS MAY BE EITHER RDLLED OR CUT.

C. TOLERANCE ON GRIP LENGTH "H" (SEE FIGURE 1) IS MINUS 3 THREADS OR 3/16 INCH, WHICHEVER IS GREATER. TOLERANCE INCLUDES COMPLETE OR PARTIAL THREADS UP TO THE VANISH PDINT.

IV. MATERIAL:

SHALL BE AS SPECIFIED ON PART NUMBER DRAWING.

PLOW BOLT - FLAT AND DOME HEAD NO. 3	DATE	CHG NO.	SPEC NO.
	JUL 30,63	12	1E44

PETERSON TRACTOR COMPANY (C)

Design of a Side Sloper

When Roy Barnes was given the design specifications for the side sloper by Mr. Peterson, he knew that a development of the moldboard would be needed so that it could be cut out of flat steel plate and then be bent to shape. The first drawing Roy made is shown in Exhibit 1. The explanatory notations were not on it originally -- they have been added for clarity -- but the drawing has not been otherwise altered. It will be noted that Roy did not always observe the usual drafting conventions. Not all views are completed; the cutting edge and the blade base both appear in the "View From Front Of Bulldozer", but some of the solid lines should be dashed (hidden) lines and some of the lines in the blade base are omitted entirely. Lines are also omitted in the other two views, including some lines which appear in the front view, and there are other lines shown solid which should properly be dashed.

When Roy began this drawing, he knew the position of the line on which the cutting edge AB would lie in top and front views from the specifications (numbers 1 and 2). He also could draw in the dozer blade and its end wing and the adjacent flange on the side sloper as they appear in the top view.

Roy knew that the cutting edge and blade base were each 92 inches long. To find the apparent blade length in the top and front views he made an auxiliary projection on an overlay sheet (not shown) in which the blade and base would appear true length. Working backwards he then determined points A and B, the two lower corners of the cutting edge. In this auxiliary view he also drew in an end view of the cutting edge and blade base. Thus he determined points C and D, the upper corners of the cutting edge and points E and F, the upper corners of the blade base. Points E and F are also the lower corners of the curved portion of the moldboard.

With the cutting edge, blade base and sloper flange already shown in the side view of Exhibit 1, Roy was able to complete this view easily. Since the two radii specified at the ends of the moldboard lie in the plane of the paper in the side view, he determined the centers of the arcs so that they would start tangent to the top of the blade base. He assumed the tangent lines would then be at 60° to the floor of the canal (the horizontal) in this view. He drew arcs EG and FH, EG of nine inch radius through 75° from its tangent line and FH of 30 inch radius (to the front of the 5/16 inch thick moldboard) through 60°. The one inch

flat at the bottom of the moldboard is bounded by C, D, E and F. Next, he added the section of the moldboard above--from the end of the small arc, G, to the top corner of the moldboard, I, and from the end of the large arc, H, to the corner, J--by drawing straight lines tangent to the two arcs at G and H. When he drew in line KL, the rearmost line in the moldboard surface, and line IJ, the top edge of the moldboard, to complete the top view, the drawing of Exhibit 1 was essentially finished. The four inch extension on the inside end of the moldboard, from line DFLHJ to line MN, was added later so that the sloper blade would overlap the dozer blade slightly.

Roy then projected the curved portion of the moldboard onto a plane tangent to the rearmost line in the top view of the moldboard (line KL) using another overlaid worksheet. This projection, shown in Exhibit 2, gave him the true length of line KL. He then began his development, shown in Exhibit 3, by drawing line KL in an arbitrary position. On both the worksheet of Exhibit 2 and the development (at this time only a line) of Exhibit 3 he drew a line perpendicular to KL through point L. This gave points O and P in Exhibit 2. To define these points on his developed view, he calculated as an approximation the lengths OL and LP as if OLP (in the bent moldboard) were a circular arc (of 30 inch radius through 60°). By going through a similar procedure at the other end of line KL, he determined the directions of the lines on which segments HG and EF, the upper and lower boundaries of the curved section of the moldboard, would lie relative to KL in the development. Roy then, as a further approximation, transferred the distances OH and FP directly from the drawing of Exhibit 2 to the development to locate points H and F, the end points of the larger radius arc, on this drawing. With three points he drew the curve FLH. He found curve EKG, at the other end of the moldboard, in a similar manner on the development; however, he located point E 92 inches from the known point F since EF was a known length--that of the cutting edge.

It was then a simple matter to add the straight lines HJ and GI at the top of the moldboard, and FD and EC at the bottom, to complete the development. Roy then added the four-inch extension for blade overlap at the dozer end--curve NM. He also extended the off end of the blade 2-1/2 inches past curve IGKEC to provide added material for trimming the moldboard to fit the "bubble" which was to be added later (see Exhibit 3 of part A). Roy drew in the ten brake lines in the part of the moldboard which was to be curved to give the millwrights an idea of how to bend it.

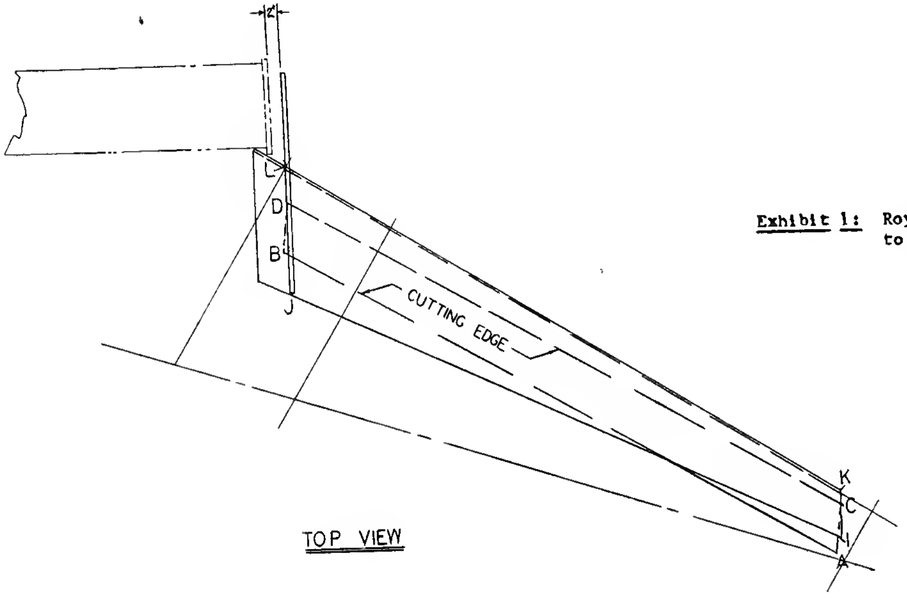
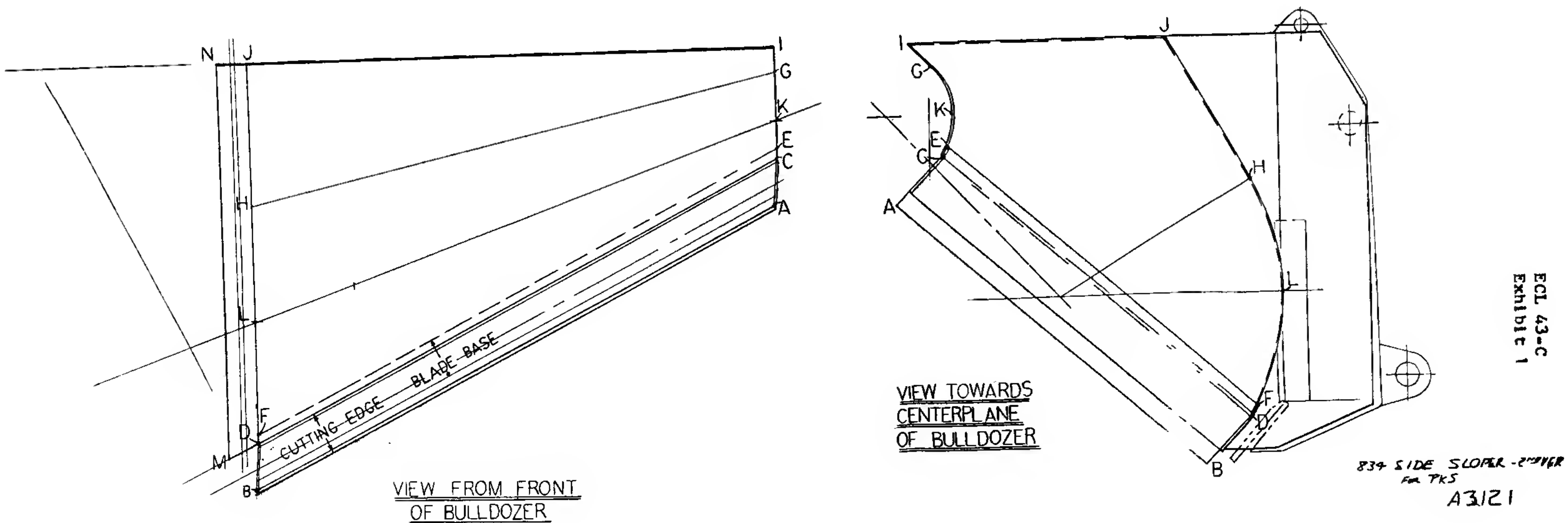
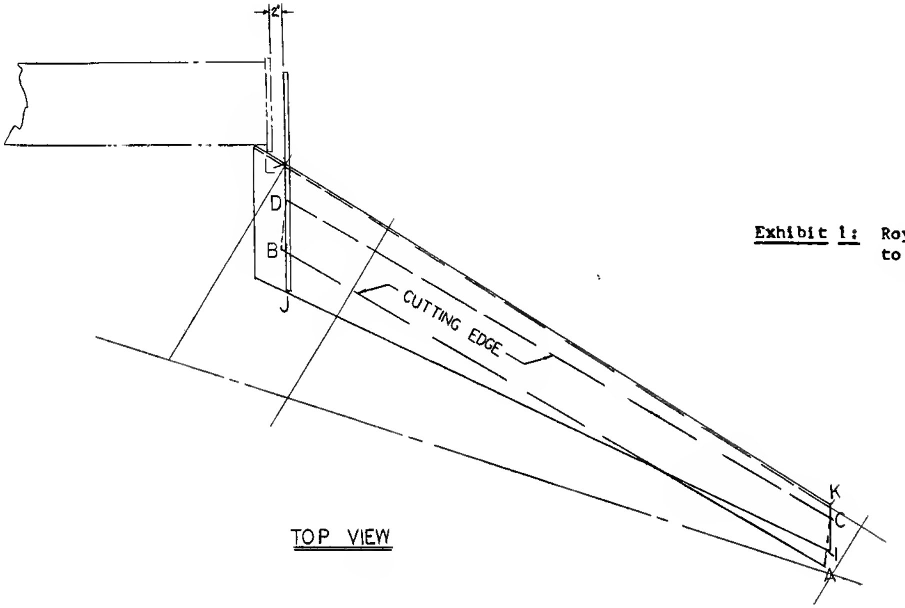


Exhibit 1: Roy Barnes' Drawing of the Side Sloper. Letters and Notes Added to Aid Explanation. No Scale.

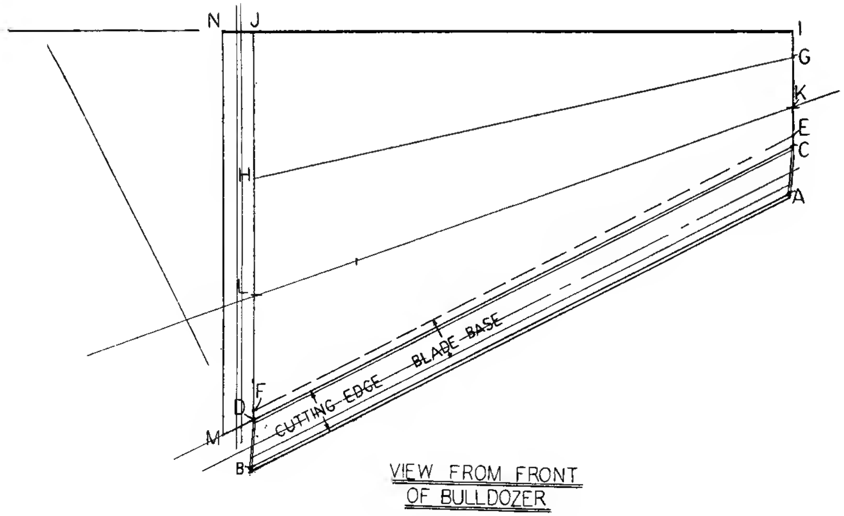


ECL 43-C
Exhibit 1

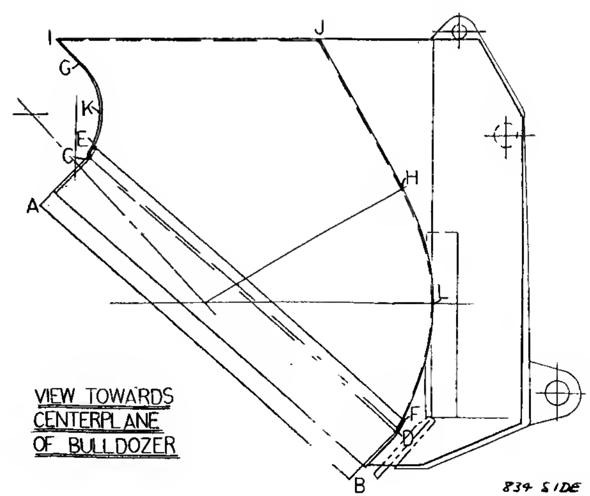
Exhibit 1: Roy Barnes' Drawing of the Side Sloper. Letters and Notes Added to Aid Explanation. No Scale.



TOP VIEW



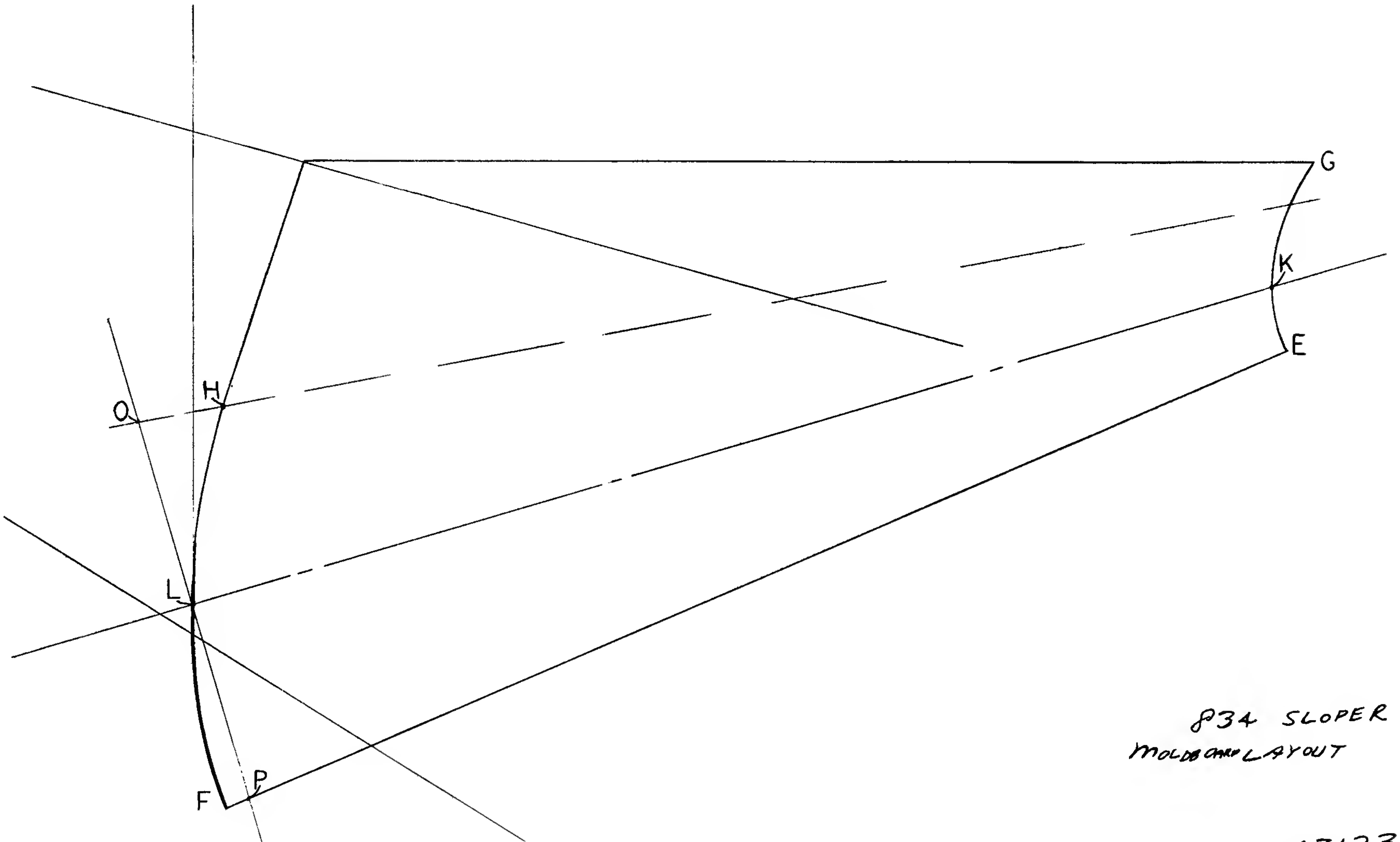
VIEW FROM FRONT OF BULLDOZER



VIEW TOWARDS CENTERPLANE OF BULLDOZER

834 SIDE SLOPER -2ⁿᵈ VER
For PKS
A3121

ECL 43-C
Exhibit 1



<u>Exhibit 2:</u> Roy Barnes' Second Overlaid Worksheet, a Projection Onto the Plane Tangent to the Rearmost Line in the Top View of the Moldboard. Letters Added to Aid Explanation. No Scale.

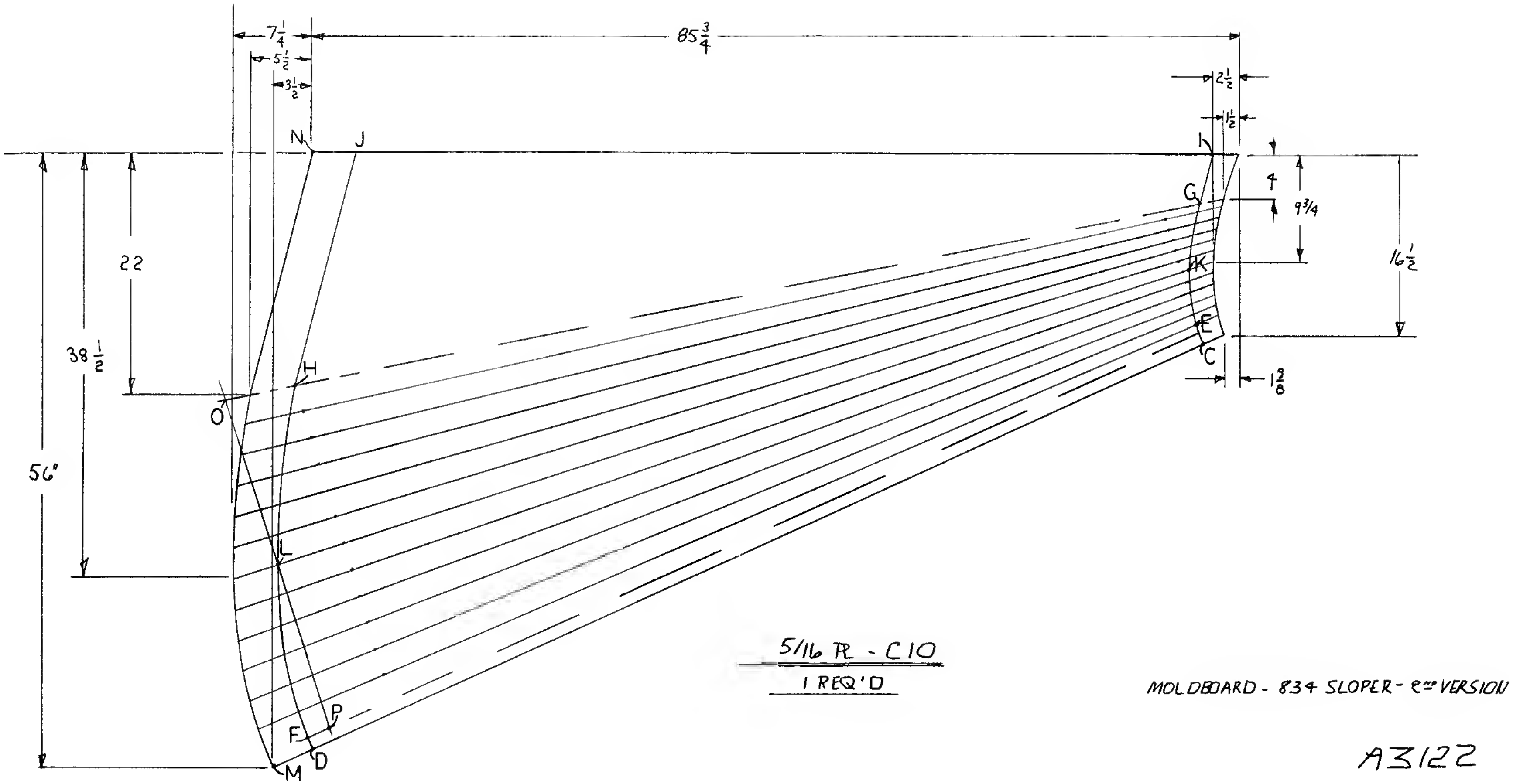


Exhibit 3: Roy Barnes' Development of the Moldboard. Letters Added to Aid Explanation. No Scale.

Instructor's Note

The side sloper case poses problems in descriptive geometry and contrasts the vague specifications used by Roy Barnes to instruct his shop for making one moldboard with the precisely toleranced specifications used by Caterpillar Tractor Company to procure cutting edges and plow bolts.

The Caterpillar drawing of the cutting edge uses "geometric tolerancing" and refers to specifications. Exhibit B2 explains geometric tolerancing. Other exhibits show the specifications.

Part B of the case contains instructor's remarks and suggested procedures for solving the problems in descriptive geometry. The procedures are explained only in words. The execution of these written instructions will require some understanding of descriptive geometry and give practice in applying the science to a real life problem. The absence of sketches which would illustrate the instructions is intended to let students feel how valualbe good sketches would be and to encourage them to use good sketches when they want to express space relations.

The procedure used by Roy Barnes is only an approximation to correct methods, but it was good enough to do the job.

This case has been used at Stanford in different ways: As a two-week assignment in descriptive geometry; as the basis for class discussion of developable surfaces; as an example to introduce geometric tolerancing. It could also serve as a basis for explanation of manufacturing methods, and heat treat distortion, or as a basis for explanations of and exercises in tolerancing.